PLANT ITEM MATERIAL SELECTION DATA SHEET

R10339150

LOP-Offgas Piping (downstream of film cooler to SBS entry)

- Design Temperature (°F): 1200
- Design Pressure (psig) (max/min): 15/FV

Operating conditions are as stated on sheet 6

ISSUED BY
RPP-WTP PDC
INIT 7/20/04 DATE

Operating Modes Considered:

- Normal operation, less than 1112 °F
- Washing of the pipeline to remove deposits

Materials Considered:

Material	Acceptable Material	Unacceptable Material
Inconel 690	X (piping)	
Inconel 625	X (piping)	
Inconel 625LCF	X (bellows)	

Recommended Material:

- **Offgas pipe:** Alloy 625 or 690
- **Bellows:** Alloy 625LCF

Recommended Corrosion Allowance: None Required.

Process & Operations Limitations:

None

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This bound document contains a total of 6 sheets.

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Corrosion Considerations:

Inconel® 690 has been used at West Valley and Savannah River Site for the melter offgas line. Because Inconel 625LCF has better fatigue properties, it has been proposed for use for the WTP LAW offgas bellows. Consequently, the question has been raised as to whether it can be used for the entire line. The following discussion reviews the behavior of alloys 690, 625, and 625LCF.

a General Corrosion
The design temperature is 1200 °F (649 °C) though normal operating temperatures will be closer to 572 °F (300 °C) with the high normal of 1112 °F (600 °C). According to the chemistry data sheet, attached, the oxygen content is about 13% or about 0.13 atm. Based on Wright (1987), the parabolic rate constant in a 0.13 atm oxygen system at 1800 °F is approximately 5×10^{-11} g^2/cm^4sec. For exposure over the five-year design life of the melter, the amount of oxidation is estimated at 3 mil (approximately 0.6 mpy) at 1112 °F.

All nickel alloys potentially suffer from the sulfidation problem. Alloy 690 with its higher chromium content is expected to be more resistant to sulfidation than the 625 series. Nevertheless, during normal operation, the sulfur to oxygen (S/O) ratio is approximately 1×10^{-3}, which is consistent with the fact that the high oxygen concentration, approximately 13%, will tend to keep the sulfur oxidized. According to Wright (1987), severe sulfidation occurs in reducing atmospheres if the S/O ratio is 1×10^{15} at about 1112 °F (600 °C). However, during normal operation at 572 °F (300 °C), oxidation is expected to predominate the corrosion reaction. Usually the lowest sulfidation temperature of concern is 1200 °F (650 °C), (Lai & Patriarca 1987), which is well above the operating temperature.

Vitreous State Laboratory, VSL, noted significant amounts of sulfate deposit during operation (Andre 2003). Andre does not note the temperature but Duratek (Duratek A) typically reports 200 °C to 600 °C (≈400 °F to 1110 °F). It should be noted that in the case of breaks in the oxide that allow contact with the deposits, rapid failure could occur because of the presence of low melting point salts, such as mixtures of Na_2SO_4, NaOH, $NaNO_2$, and $NaNO_3$, that can act as a flux at temperatures as low as 154 °C (310 °F). After about 3 years of operation with an alloy C-276 offgas line, Andre (2003) reported no sulfidation or corrosion in the offgas line.

Duratek (Duratek B) tested several nickel base alloys, Table I, in the pilot plant melter offgas line. Alloy 690 averaged about 0.3 mpy. Although alloy 625 was not tested, it should perform similarly to alloys C-22 and C-276.

Table I - Offgas Corrosion Rates

Alloy	C-22	C-276	6025HT	690	310	HR160
Corrosion rate, mpy	0.81-1.2	0.43-0.93	0-0.17	0.3	1.1	0.56-1.8

Discussions with staff familiar with West Valley and VSL studies, suggest the periodic washing of the offgas line does not significantly affect the uniform corrosion rate.

Conclusion:
Although nickel base alloys are potentially susceptible to sulfidation above about 1110 °F (600 °C), the atmosphere in the offgas line is sufficiently oxidizing to inhibit it for the listed alloys. Alloys such as 690, 625, 625LCF, and even C-22 and C-276 are acceptable and have roughly the same corrosion behavior. Because the piping is maintainable, and because the piping is thick and is carrying only hot gas, no corrosion allowance is necessary.

b Pitting Corrosion
Pitting corrosion, as such, is not feasible under the proposed operating conditions.

Duratek (Duratek B) also observed that pitting rates, Table II, typically were much less than 1 mpy. Again, alloy 625 was not tested but should perform similarly to alloys C-22 and C-276. The most likely occurrence of pitting is during, or shortly after the duct is washed to remove deposits.

Table II - Offgas Pitting Rates

Alloy	C-22	C-276	6025HT	690	310	HR160
Pitting rate, mpy	0.08-0.16	0.06	0.4	0.04	0.15	0.15-1.8

Conclusion:
No significant pitting concerns exist for the potential alloys of choice.

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c End Grain Corrosion
Not applicable to this system.

Conclusion:
Not applicable to this system.

d Stress Corrosion Cracking
The high nickel content of the various alloys is expected to inhibit chloride stress corrosion cracking under aqueous conditions.

Long-term operation in the 800 °F to 1650 °F (425 °C to 900 °C) range leads to carbide precipitation, with the carbides forming faster as the temperature increases. At the normal operating temperature, all of the alloys in question will experience carbide formation with a subsequent decrease in ductility.

Conclusion:
The dry environment should minimize stress corrosion cracking and intergranular corrosion.

e Crevice Corrosion
See Pitting.

Conclusion:
See Pitting.

f Corrosion at Welds
Low carbon alloys will be less likely to sensitize.

Conclusion:
No problem expected.

g Microbiologically Induced Corrosion (MIC)
Temperature exceeds values where microbes are viable and therefore MIC is not a concern.

Conclusion:
Not a concern.

h Fatigue/Corrosion Fatigue
Stresses from pressure effects are expected to be small because of the low, near atmospheric, operating pressure and the relatively small pressure fluctuations. Higher stresses are expected in the bellows due to thermal cycling.

The Special Metals technical manuals for alloy 690 (2002), alloy 625 (2002), and alloy 625LCF (2003) show that fatigue resistance increases for the alloys in the order shown. Therefore, the high corrosion resistance of 625LCF combined with its improved fatigue strength makes it the preferred choice for the thin ply bellows.

Conclusion:
Alloy 625LCF should be used for the thin ply bellows. Alloys 690 and 625 are acceptable for the balance of the offgas system piping.

i Vapor Phase Corrosion
The entire pipe is "vapor phase" and its expected performance is discussed in section 'a'.

Conclusion:
Not applicable

j Erosion
The offgas flow rates are sufficiently low that solids deposit in the line. Therefore, erosion is not expected.

Conclusion:
Erosion is not a concern.

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k Galling of Moving Surfaces
Galling is not considered important since there are no frequently cycled sliding joints.

Conclusion:
Galling is not a concern.

l Fretting/Wear
No tight sliding joints are present.

Conclusion:
Fretting is not a concern.

m Galvanic Corrosion
The pipe is all one material and normally dry. Galvanic corrosion should not occur.

Conclusion:
Not a concern.

n Cavitation
Flowing fluids are not present.

Conclusion:
Not a concern.

o Creep
According to the 625 and 625 LCF alloy data, creep is not a significant concern at or below 1110 °F (600 °C) although most nickel alloys, including alloy 690, begin to exhibit creep at temperatures above 1000 °F (535 °C).

Conclusion:
Not a concern during normal operation at 572 °F (300 °C) for any of the three alloys.

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References

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2. Duratek A, *RPP-WTP Pilot Melter Off-gas Treatment System Corrosion Test Results Report*, TRR-PLT-22A, Rev 0, GTS Duratek, Columbia, MD
3. Duratek B, *RPP-WTP Pilot Melter Off-gas Treatment System Corrosion Test Results Report*, TRR-PLT-22B, Rev 0, GTS Duratek, Columbia, MD
4. Inconel alloy 625, 2002, Publication Number SMC-063, Special Metals Corporation
5. Inconel alloy 625LCF, 2003, Publication Number SMC-020, Special Metals Corporation
6. Inconel alloy 690, 2002, Publication Number SMC-079, Special Metals Corporation
7. Lai, GY & CR Patriarca, *Corrosion of Heat-Treating Furnace Accessories*, In: Davis, JR (Ed), 1987, *Corrosion, Vol 13*, In "Metals Handbook", ASM International, Metals Park, OH 44073
8. Wright, IG, *High-Temperature Oxidation*, In: Davis, JR (Ed), 1987, *Corrosion, Vol 13*, In "Metals Handbook", ASM International, Metals Park, OH 44073

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1. Amrhein, GT, 2002, *Fate of Mercury in Wet FGD Wastes*, McDermott Technology Inc.

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OPERATING CONDITIONS

Materials Selection Data

Component (Name/ID) Melter Offgas Line to SBS
System LOP (LAW Melter Primary Offgas)

Operations

Chemicals	Unit	Cold Startup	Normal Operation	High Normal	Cleaning	Accident
Oxygen	%	20	13	15	NC	7
Chlorine	ppmv	0	trace			
Fluorine	ppmv	0	trace			
Nitric Oxide (NO)	ppmv	0	4000	7000	NC	10000
Nitrogen Dioxide (NO2)	ppmv	0	2000	4000	NC	6000
Sulfur Dioxide (SO2)	ppmv	0	8	55	NC	200
Ammonia (NH3)	ppmv	0	50	100	NC	200
Carbon Monoxide (CO)	ppmv	0	400	600	NC	2000
Carbon Dioxide	%		2	2.5	NC	5
Particulate	g/dscf	0	0.033	0.05	N/A	0.2
Hydrochloric Acid (HCl)	ppmv	0	5	10	NC	20
Hydrofluoric Acid (HF)	ppmv	0	12	20	NC	40
Water (H2O)	%	0	35	40	60	80
Vacuum	in. W.G.	2	6	7	6	25
Temperature	^{o}F	6	930	1110 (~600^{o}C)	750	1650 (~900^{o}C)
Velocity	fps	70	60	100	70	150

Comments: Base material selection on 600^{o}C max.

N/A = Information not available
NC = No Change

† List expected organic species:
Use maximum of 2 significant figures